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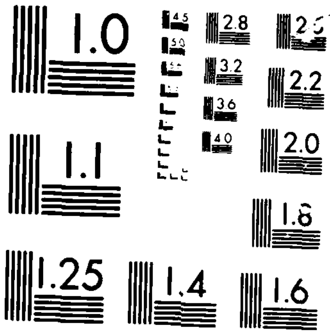

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THESIS

A LOCAL AREA NETWORK TO FACILITATE OFFICE AUTOMATION
IN THE ADMINISTRATIVE SCIENCES DEPARTMENT

by

William Howard Peck

March 1986

Thesis advisor: Norman F. Schneidewind
Co-advisor: M. P. Spencer

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This thesis is not intended to be a text on the technical aspects of LAN engineering. It is intended to help management personnel become familiar with the basic concepts, vocabulary, and resources available so that management can make enlightened decisions concerning LAN design and implementation.

While this thesis will focus on a specific organization the information is applicable to other organizations that are contemplating a LAN to facilitate office automation.

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A Local Area Network to Facilitate Office Automation in the Administrative Sciences Department

by

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Lieutenant, United States Navy
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ABSTRACT

This thesis explores the implementation of a Local Area Network (LAN) to increase the usefullness of microcomputers in an office environment by linking individual microcomputers and associated peripheral devices together into a communications network. The target site is the Administration Sciences Department at the Naval Postgraduate School, Monterey, California.

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While this thesis will focus on a specific organization the information is applicable to other organizations that are contemplating a LAN to facilitate office automation.

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I. INTRODUCTION

The microcomputer's ability to do wordprocessing tasks and support decision making has earned it a prominent place in today's office. This thesis will explore the implementation of a Local Area Network (LAN) to increase the usefulness of microcomputers in the office environment by linking individual microcomputers and other peripheral devices together in a communications network.

The target site will be the Administration Sciences (AS) department at the Naval Postgraduate School (NPS), Monterey, California. Desired features for an AS department LAN will be discussed along with the technology that will be required to implement these features. A sample of available LAN products will be presented and from these a recommendation for hardware and software will be made.

A LAN is an important step in office automation. It represents a management decision to include information as a vital resource of an organization as well as a commitment of physical resources to a project. In order to remain competitive in an information hungry society new communication channels must be opened and old communication channels enhanced.

Information is especially important in an academic environment. Education is a labor intensive and information critical by nature. The military students who attend NPS are experienced, well trained officers that are sorely needed in their parent organizations. Quality professors in computer related fields are scarce and their time is limited. Any scheme that reduces the professor's time spent on collateral duties or increases the quality of education of the students will facilitate the completion of the school's primary goal of education.

While this thesis will focus on a specific organization the process by which a LAN is chosen will be similar for other office automation projects. Each organization has peculiar requirements that must be met but the basic principles of LAN architecture and the services that are available remain the same.

This thesis is not intended to be a text on the technical aspects of LAN engineering. It is intended to help management personnel become familiar with the basic concepts, vocabulary, and resources available so that managers can make enlightened decisions concerning LAN design and implementation.

A. BACKGROUND INFORMATION

The Administration Sciences department is headquartered on the second floor of Ingersoll Hall, a three story structure on the Monterey campus. The AS department utilizes roughly one fourth of the building with the remainder being used for classrooms, office spaces, and the School's main frame computer and support personnel.

The AS department has four administrative offices and forty- three faculty offices in Ingersoll Hall. The four administrative offices are for the department Chairman, the Chairman's secretary, the support services supervisor and his assistant and the clerical support staff.

There are sixty-two faculty in the AS department of which fifty-one have spaces in the target site. Because of the limited space available some of the faculty must share offices.

With respect to its use of microcomputers, the AS department is the "contagion" phase of data processing evolution as described by Nolan [Ref. 1]. As can be seen in Table I, the AS department has a significant inventory of microcomputers and peripheral equipment. Due primarily to the various research activities of faculty members, a high

percentage of the faculty have and use microcomputers. While the proliferation of micros obviously helps individual productivity, there is vast potential for organizational productivity that is not being tapped.

TABLE I

COMPUTER ASSETS

COMPUTERS	NUMBER
IBM PC	42
XT	13
AT	3
COMPAQ	6
PRINTERS	
Dot Matrix	36
Daisy Wheel	15
Hard Disk Storage	
10 Mb	29
20 Mb	3
40 Mb	2
72 Mb	1

A LAN is a means of harnessing the synergism of an information dependant organization. Office automation is here today. Evidence of this can be seen in the personal computer that adorns almost every desk in almost every office. A LAN provides the means to link all of these islands of information in an organization into a corporate wide information network. The AS department has already acquired microcomputers for a significant number of its faculty and encourages their use. The next logical step is to plan and implement a Local Area Microcomputer Network to link all of the individual micros into a cohesive unit.

B. LAN ADVANTAGES

There are two main advantages associated with the implementation of a LAN. The first is economic efficiency and the second is personnel effectiveness.

A LAN allows the sharing of resources thereby reduci·g the overall cost of computing to an organization. At the same time the ability to share resources allows an organization to purchase unique or expensive peripherals that could not normally be justified by the need of only one isolated user. Thus the cost of computing is reduced while the quality of services can be enhanced.

AN example of a needed but shareable resource is the printer. A recent survey of the AS department faculty (see Appendix) revealed that 40% of those faculty that had access to a microcomputer and printer used the printer to printout less that ten pages per week. This is poor utilization of a costly resource. Department-wide the utilization of printers attached to microcomputers is very low.

A LAN would not greatly reduce the number of draft quality printers that would be needed by the AS department because a readily accessable printer is an essential element of a micrcomputer workstation. The benefits in this area would come from access to higher quality, faster and more diverse printers that could not be justified for a single user.

Almost all peripherals can be shared to reduce overall system costs. Some common shared peripherals are:

- Printers
  - Dot Matrix
  - Daisy Wheel
  - Laser
  - Color
  - Graphics
- Disk Storage Devices
- Print Spoolers
- Modems
- Multi-Color Plotters

Personnel effectiveness is not as easily quantifiable as economic efficiency. One must judge rather than measure what the value of information is to an organization. In an academic environment information is vital. Research and

education are information intensive activities. The presence of so many microcomputers and so much data storage (Table 1) in the AS department attest to the priority of information in the AS department. The opportunity lost by the suboptimal utilization of a professor's time is much greater than just their salaries.

C. LAN ABILITIES

The ideal LAN should be inexpensive to build and operate, offer fast service, be reliable, easily maintainable, expandable, user friendly and adaptable to new technology and user needs. It should also facilitate complete distributed processing [Ref. 2] by allowing the operating system, applications software and data to be distributed throughout the nodes of the network. This ideal has not been implemented into a microcomputer LAN as yet despite the advertising to the contrary. Lack of software is the major limiting factor in the performance and operability of almost all computer projects including a LAN.

Some of the service that are desired are:

- Resource sharing
- File transfer
- Interactive, terminal oriented message service
- Electronic Mail
- Electronic calendars listing meetings and events
- Organization wide data base management system
- Electronic directories for phone, research topic areas and points of contact
- Management of multi-author documents and research
- On line storage of instructions and notices
- Financial programs for budget planning, submission and tracking

II. LAN DESCRIPTION

Schneidewind [Ref. 3], describes a Local Area Newtork as "..... a data communications system that allows communication between a number of independent devices." While communication is the ultimate product of a LAN, the means by which the communication is accomplished must be understood before management can make sense out of the pleathora of LAN offerings on the market.

The first choice that must be made is the scope of communication that will be supported. Computerized bits and bytes are not the only form of data that constitute communication. A ful service LAN can be designed to transmit voice and video as well as computer data.

A. PHYSICAL COMPONENTS

A LAN requires a transmission medium to connect all of the work stations, called *nodes* in the LAN vernacular, togehter and a signalling method in which to convey information. The topography of the LAN describes the layout of the medium and the nodes. The access method is the means by which nodes gain access to the medium in order to communicate with other nodes. Finally, protocols determines how the message is formatted so that it can successfully traverse the LAN to its destination and be readible when it gets there.

1. Signalling Method

The signalling method is the means by which information is passed through the transmission medium to the various nodes of the LAN. There are two methods of signalling; digital and analog. Digital signals require the medium to take on two different states, such as a positive voltage and a negative voltage in the case of wire media.

This is the same binary method that a computer uses to represent information internally. Because there are no conversions required for simple digital signalling this is the most common method for a computer to communicate with an attached peripheral such as a printer or disk storage device.

Analog signals are continuous waves similar to sound or radio waves. Information is conveyed by varying the amplitude, frequency or phase of the waves. Because computer data must be in a digital format various techniques have been developed to transmit digital data using analog signals. In all cases some additional hardware is needed to convert the digital data into an analog format and back again. A modem or modulator/demodulator is commonly used for this purpose.

A full service LAN that will carry voice or video is not limited to analog signaling methods. In a method similar to that used by a compact disk player, analog data can be represented numerically (digitized) in order for it to be transmitted using digital signals. Thus a single method of signalling can be used to send both digital and analog data with the proper conversion hardware. The method that is used is dependent upon the transmission medium, the distance between nodes and the topography of the network.

Digital signals attenuate and become undecipherable more quickly than do analog signals. This can be overcome by placing repeaters that receive, decode and then retransmit the signal at regular intervals. Analog signals have a greater range than digital signals but require a modem at each node. These are just some of the trade-offs between the two signalling methods that must be considered.

2. Transmission Medium

The transmission medium is the physical connection that forms the information pathway between the nodes.

Typically the medium is some form of wire but optical fiber has also been used. There are even networks that use the installed electrical service wiring as a medium. There are no restrictions on transmission medium imposed by the nature of the AS department LAN; however more support is available for twisted pair and coaxial cable, the two most common transmission mediums.

a. Coaxial Cable

The most versitile medium in use today is coaxial cable. The two most commonly used coaxial cables are: 50 ohm coaxial cable that is often refered to as baseband cable and 75 ohm coaxial cable that is often refered to as Community Access Television (CATV) cable.

Coaxial cable consists of a soild wire core that is surrounded by an insulating sheath. This sheath is itself surrounded by a braided wire shield that is in turn covered by an outer layer of tough protective insulation.

While they are both physically similar, 50 ohm cable is only used for digital signaling. Data transmission rates of 50 million bits per second (Mbps) can be achieved over a distance of a few thousand meters using baseband coaxial cable.

CATV cable can be used for analog or digital signaling. When used for digital signaling it has many of the same limitations as baseband coaxial cable. When used with analog (single channel) signaling CATV cable can achieve data transmission rates of over 50 Mbps over short distances of a few thousand meters. When CATV cable is used for a special type of analog transmission called Frequency Division Multiplexing (FDM) it is called broadband cable. FDM divides the frequency spectrum of the cable into small bands, similar to radio frequency bands, to form individual channels within the cable itself. This concept allows as many as two thousand separate channels to be created on one

cable. The channels can represent dedicated lines between microcomputers and peripherals, separate LANs using the same cable or mixed use between voice, video and computer data all on one cable.

One of the advantages of CATV cable is its familiarity. This medium, as its name implies, is widely used in the television industry. The versatility of CATV cable is a definite pluse for its use in local area networks.

A good metaphor to help to explain the differences between baseband and broadband capabilities can be found in a recent LAN advertisement by Sytek, Inc. It describes baseband cable as a one lane highway with data able to go in either direction but only one direction at a time. Similarly broadband is described as a multi-lane highway with data able to go in both directions at the same time.

b. Twisted Pair

The most common transmission medium is twisted pair. This is literally a pair of insulated wires that are twisted into a spiral to reduce electromagnetic interference between the two wires. It is most commonly used for telephone connections. Both analog and digital signaling can be used on twisted pair over a distance of 2 to 5 thousand meters. The data transmission rate for digital signals is low at only a few megabits per second. For analog signals using modems the data transmission rates fall below 10 thousand bits per second but twisted pair can be broken down into channels similar to broadband cable to improve the data transmission rate somewhat. The limitation here is with the commercially available modems which breakout only a few channels.

c. Optical Fiber

New technology has made optical fiber a viable medium for local area networks. Typical data transmission rates are around 10 Mbps with a range of a few thousand meters without repeaters. Rates in the 100-400 Mbps range have been achieved with repeaters. Optical fiber is not susceptible to electromagnetic interference as are all of the above wire mediums. It is also much more difficult to intercept optical fiber transmissions for espionage purposes, for example.

The difficulty with optical fiber comes during installation. The fibers are very small and delicate, making connections difficult and costly. The cable is susceptible to breakage if bent too severely, thus limiting cable routing somewhat. As technology advances in this area, optical fiber will see increased use as a LAN medium but at present its high costs make it unsuitable as a medium for an office LAN, as the AS department is proposing.

3. <u>Topology</u>

LAN topology concerns the physical layout of the individual devices within the LAN and the routing of the medium between the nodes. It is impractical to connect every computer and every peripheral device together using separate cables. A modest installation consisting of five computers would require 10 seperate cables and the ability to switch between them to connect all of the nodes (see Figure 2.1). Doubling the number of nodes to ten increases the number of cables required to directly connect each node to 45. LAN topologies reduce this problem.

There are three major topologies to choose from: bus, star and ring. Slight modifications of these three basic topologies are abundantly available and each vendor has his own name for his product. The following descriptions should help the reader navigate between the myriad of

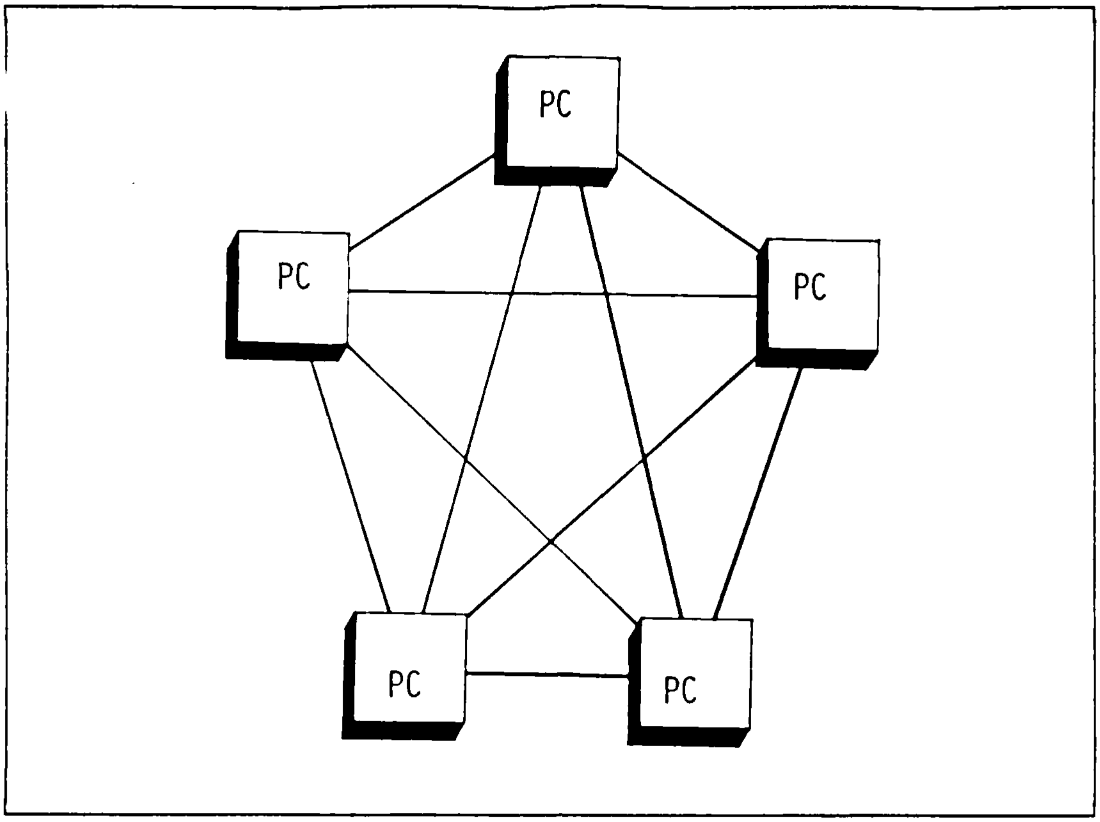

Figure 2.1 A Modest Fully Connected Installation.

LAN topologies with few difficulties. A comparison of the advantages and disadvantages of the various LAN topologies can be found in Table II.

a. Bus Topology

A baseband bus (Figure 2.2) is simply a single cable with a terminator at each end that prevents reflections of signals back down the bus [Ref. 5: pp. 25-29]. Nodes are attached to the cable via taps that must be precisely placed to prevent reflections from causing interference with the data signals. A transceiver allows the node to communicate with the bus through the tap. When a signal is introduced into the bus it travels in both directions (bidirectional) until it reaches the terminators. Along the way the signal is received by all of the active

TABLE II

COMPARISON OF LAN TOPOLOGIES

Medium	Signaling Technique	Maximum Data Rate (Mbps)	Maximum Range (km)	Applicable Topology: Bus	Tree	Ring	Star
Twisted Pair	DIGITAL	4	1-3	X		X	X
Coaxial Cable (50 OHM)	DIGITAL	50	1-3	X		X	
Coaxial Cable (75 OHM)	DIGITAL	50	1	X		X	
	ANALOG WITH FDM	20	10-30	X	X		
	SINGLE-CHANNEL ANALOG	50	1	X		X	X
Optical Fiber	ANALOG/DIGITAL	400	1-5	X		X	X

transceivers on the bus. Data is typically sent in packets that contain a destination address, origination address, error checking code and finally the data. The logic in the tranceiver can identify packets that have its address and route those messages to its connected node. Error checking can also be done at this point to ensure that the message was correctly received as sent.

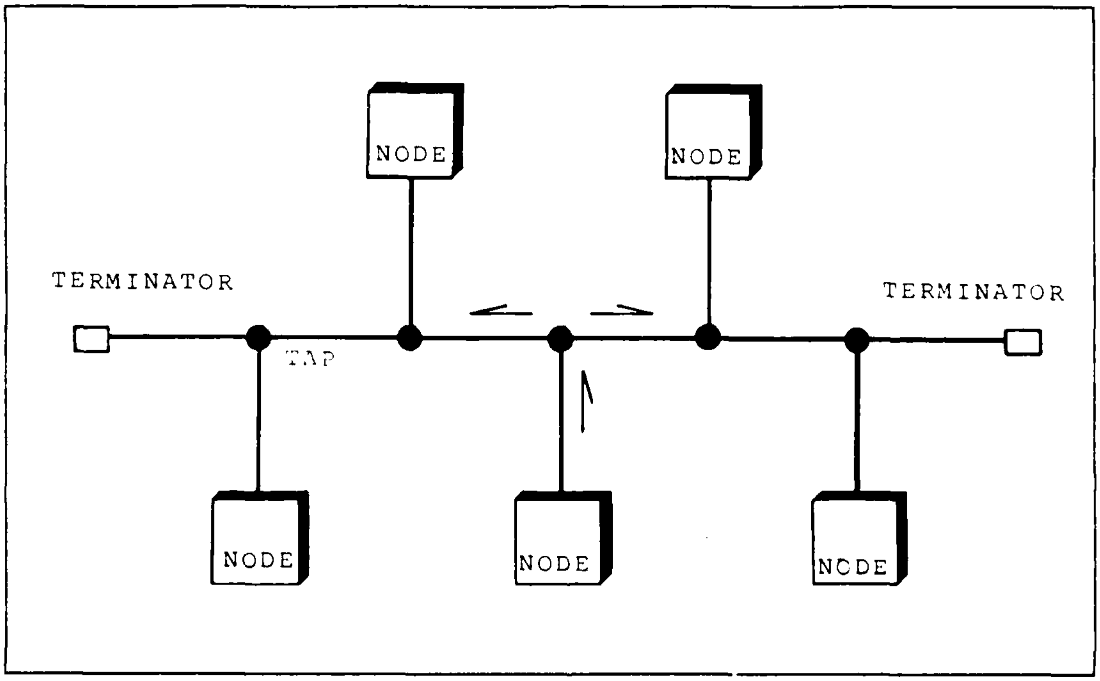

Figure 2.2 Baseband Bus.

Broadband signals propagate in only one direction [Ref. 6: p.81] making the medium unidirectional. This requires a separate path for the nodes to transmit on and a separate path for the node to receive from. For this reason either two cables must be used to form the bus or frequency division multiplexing must be used to create two logical channels on the cable (Figure 2.3)

When using FDM, the headend servs as a frequency converter. The frequency converter receives the incoming

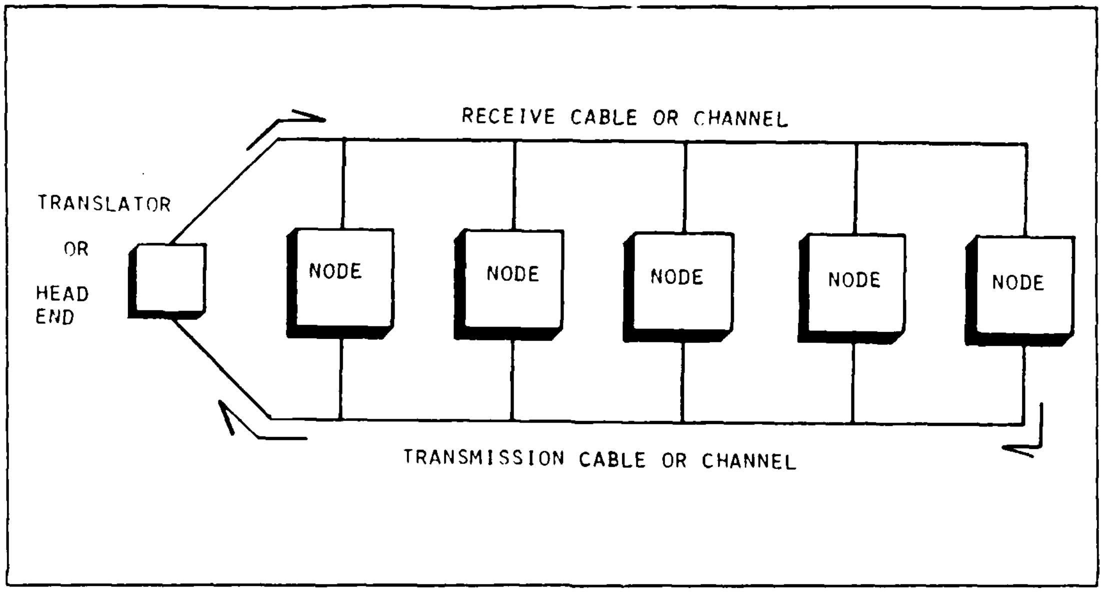

Figure 2.3 Broadband Bus.

signal on the transmit frequency and then retransmits the information to the bus on the receive frequency. When FDM is not used, the headend of the cable is passive. The transmit and receive cables are connected into one large cable with the headend in the center. There is no difference between the transmit and receive frequencies. Each node has two cable connections. The transmitters and receivers are separate units to decrease interference.

The tree topology is a common modification of the bus. It is essentially a series of busses connected to a backbone bus [Ref. 5: p. 29]. The tree network is practical only for broadband busses where one cable can be used for both transmission and reception. Repeaters are used to connect the branches of the tree to the central cable.

b. Ring Toplogy

Stallings [Ref. 6: p. 88], describes a ring as ". . . a number of repeaters, each connected to two others by unidirectional transmission links to form a single closed path" (see Figure 2.4). The repeaters can connect to single

devices, multiple devices or other networks (including other rings).

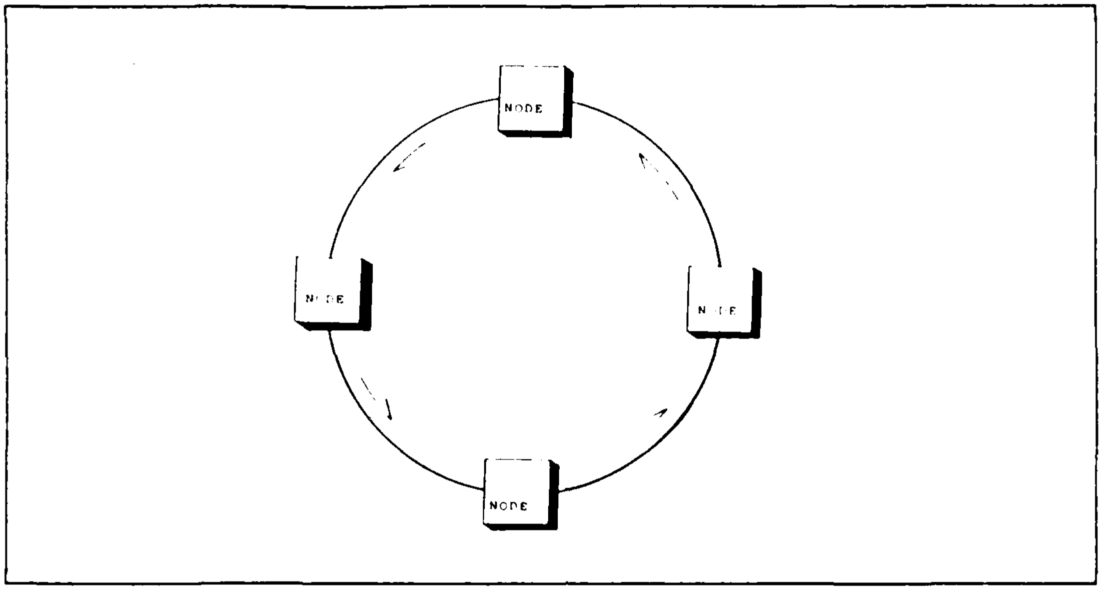

Figure 2.4 Ring.

To operate, a node sends a data packet to its repeater for transmission on the net. The message goes to the next repeater in the ring which examines the address portion of the packet to see if the message is for its node. If this is not the case, the repeater retransmits the message to the next node in the ring. This continues until the message reaches its destination and the message packet makes a full circuit of the ring back to the original node.

The major disadvantages of ring networks are susceptibility to failure and complexity. If any one of the repeaters in the ring fails the entire ring is inoperable. However there are ways to bypass a failed repeater but this adds to the complexity of the ring.

There is no central controller for a ring so some method must be used to determine when a node can transmit and to distribute the ability to transmit evenly

throughout the different nodes. This is usually accomplished by use of a circulating token, a special type of message, which gives permission to transmit, when it is received by the node. There must also be some provision for removing messages from the ring so that they do not get continually repeated.

c. Star Topology

A star consists of a central hub with separate communication links to each of the other nodes that spread out like the spokes on a wheel (Figure 2.5). The transmitting node, sends a message which is relayed through the central hub to the desired destination. When the connection between the two nodes is continuous as as in a telephone system, the central hub is said to be providing circuit switching. If the connection is only long enough to send one packet of information then the system is a packet switching network.

The comparison of the star topology to the telephone system is important. If a Private Automatic Branch Exchange (PABX) is already installed, then it may be possible to utilize the existing telephone system to provide the communication linkages needed for the computer network. Some modern PABXs are computerized and use digital signals for control and data. Modems would not be required in this instance. The computer itself could generate the proper signals to perform the desired connections. This system could support both packet and circuit switching techniques.

The major problem with a star network is the central hub. If the central node fails, then the system is totally inoperable. For this reason many star networks employ backup central controllers. Data transmission rates for a star network are not as high as those for other topologies but should be sufficient for most office applications.

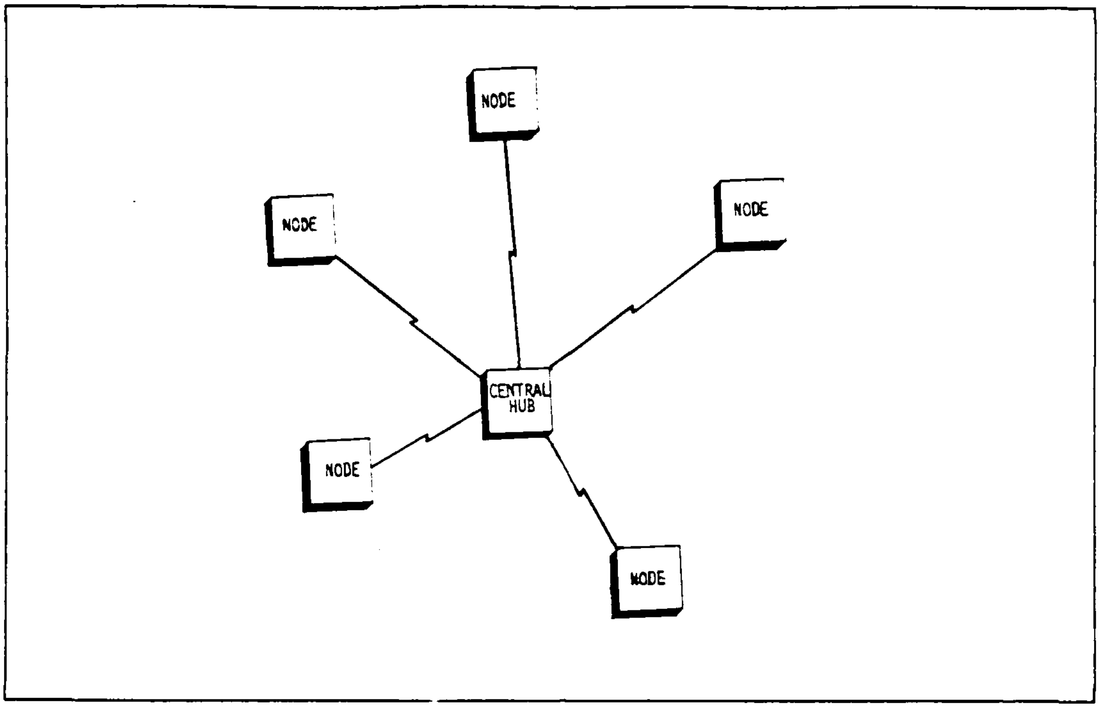

Figure 2.5 Star.

4. <u>Access Methods</u>

Access method is the means by which the various nodes of a LAN share the use of the LAN. In describing the different topologies nothing was said specifically about how the nodes would use the LAN. A bus is a multipoint medium [Ref. 6: p. 74] that allows only one node at a time to transmit. The nodes on a bus must therefore contend for access to the network. A ring uses sequencing to pass access from node to node requiring each node to wait its turn before being allowed access to the network. A star uses circuit switching instead of messages packets to facilitate communication between nodes. Access in a star network is controlled by the central switch.

a. Bus Access Methods

On a bus network it is possible for two nodes to desire access to the network at the same time. What happens

when these two nodes decide to transmit simultaneously? When the two transmissions meet or collide the resulting changes in the medium that normally convey data will render both transmissions undecipherable. This is termed a collision.

It is obvious that some method must be used to prevent message collisions. There are various way that a a network can handle contention for services. The following will discuss the major methods of resolving contention and determining access to a network.

A key element in all LAN transmissions is the acknowledgement. Without an acknowledgement there is no way to determine that a message has been correctly delivered to a destination. One method that could be used to control access to a network is no control. Pure ALOHA is the name of a network in Hawaii made up of radio transmitting stations that used this method. [Refs. 5,6: pp. 68-75, pp. 112-114] In this system a node simply transmitted its message at an arbitrary time and waited for an acknowledgement. If collisions with other messages occurred, an acknowledgement would not be returned and after a predetermined amount of time, the message originator would try again. This method is not very efficient at even modest loads and would not be used in a microcomputer LAN.

An improvement to Pure ALOHA is Slotted ALOHA. With this method all of the nodes must be synchronized to a common clock. Transmissions are only allowed at certain time periods. Although this does not prevent messages from interfering with each other, it does increase throughput by reducing the amount of time that competing messages block the network. For a collision to occur in pure ALOHA, a node only has to begin transmitting any time during another node's transmission. This could conceivably block the network for a time equal to that required to transmit two

message packets. In Slotted ALOHA both transmissions would be synchronized and only one time period would be lost to interference, thereby increasing the throughput of the system.

The requirement to have all stations on the network synchronized makes Slotted ALOHA more complicated that Pure ALOHA, without a major increase of throughput under high load conditions. As with Pure ALOHA, Slotted ALOHA is too inefficient to be practical for microcomputer LANs and therefore is not used by microcomputer LAN vendors.

b. Carrier Sensed Multiple Access (CSMA)

CSMA is a "listen before talk" access method. The transmitting node listens to the medium to determine if it is already in use. If the network is not in use, the node transmits its message packet and waits for an acknowledgement. If the network is busy, then the node waits for the LAN to be idle before it transmits.

This access method reduces the chances of a collision dramatically. Because of the propagation delay inherent in a LAN though, it is still possible for two nodes to determine that the network is idle and transmit at the same time resulting in a collision. If this happens, there will be no acknowledgement for either party. In this case both nodes have the option to retransmit their messages after timeout (the time the computer waits for an acknowledgement) has occurred. To keep two nodes from continually interfering with each other, different timeouts or built-in delay schemes, are used to allow one node to successfully complete its message.

If the network is busy when a node desires to transmit, then the node must wait. If more than one node is waiting for the network to clear, then interference is almost certain as each node will begin to transmit as soon as the network is idle. To resolve this, a probability

scheme has been developed to randomly determine a waiting period between the time a node determines that the network is idle and the time it can transmit a message on the network. If the node senses that the network is still in use at the end of its waiting period, it will again wait. Some schemes modify the probability factors that a node uses to determine wait times. Otherwise, a node could conceivably never get the chance to transmit on the network.

As with the ALOHA method of access, if interference occurs, it is possible for the LAN to be blocked form transmission. This can be significant during times of high network utilization. CSMA with Collision Detection (CSMA/CD) is a method of increasing the throughput of a bus or tree LAN by announcing that a collision of two messages has occurred. This is often called "Listen while talk."

Remember that on a bus, messages are transmitted to all stations on the network via a separate channel or cable. If a transmitting node listens as it transmits, it can detect its own transmissions and determine if a collision has occurred. If the node determines that a collision has occurred, it stops its transmission and broadcasts a jam signal to alert the network that the collision has occurred and waits to begin retransmission.

Because propagation times through the network are usually much shorter than the time it takes to transmit a complete message packet (for this method to work the transmission time must be longer than the propagation time) less time is lost to collisions because the entire message packet is not transmitted. Networks that utilize a significant amount of their transmission capacity can experience increased throughput using CSMA/CD.

c. Ring Access Methods

One way to avoid contention for network access is to provide that access be sequence for all of the nodes

on the net. Sequencing is the key to the ring access method. A message is circulated from node to node in the net using a predetermined sequence. In a true ring topology the sequence is determined physically. Each node is connected to only two other nodes in a ring. One node is its predecessor in the ring and is the source of its messages. The other node is its successor in the ring and receives all of its messages. Logical rings may be formed on bus networks by utilizing the addresses of the nodes to determine the sequencing.

In a token passing ring, access to the network is gained by capturing the "token." The token is actually a specific bit pattern in a message which indicates access approval to the network. Before a node can transmit a message, it must receive the token from its predecessor in the network.

When it receives the token, the node removes the token (changes the bit pattern) and sends its message packet. The new message is passed in sequence from node to node until it gets to the destination.

The destination node identifies its address on the message, reads the message, places the appropriate acknowledgement mark on the message and then sends the message on around the ring until it gets to the originator. The originator recognizes its message and looks for the acknowledgement to indicate a successful message transfer. At this point the originating node relinquishes control of the network by sending a token to the next node in line.

Variations on token passing access allow a node to send more than one message after capturing the token. Limits are placed on the number of messages that can be sent or by the amount of time that can elapse before the node must relinquish control of the network.

Messages that are sent via computers are usually of fixed length. Long messages must be broken down into smaller units and small messages must be padded to the appropriate length. A slotted ring makes use of the fixed length of a message to control access to the network.

Slotted rings use a fixed number of fixed length message slots that are continually circulated around the net. When an empty slot is received by a node it can fill that slot with its own message. When the destination node receives the message it has a space in the slot to mark its acknowledgement. After the message makes a complete circle of the net, the originating node removes its message from the slot, notes the acknowledgement, and transmits an empty slot to the next node in sequence.

Rings are more complicated in operation than are busses. To start up a token ring, some node in the network must be identified to send the original token. Thereafter the network must be monitored to determine if the token has been lost (caused by electromagnetic interference or hardware failure). A slotted network must be similarly initialized and monitored. In a true ring topology network the failure of a node breaks the ring and causes the whole network to fail. However, there are methods, such as wiring centers, to avoid this catastrophy. A physical bus using a logical ring access method may be able to bypass a failed node using complicated software procedures.

A ring network requires a lot of overhead to operate. This reduces the throughput of the system under low load conditions. If only one node wished to utilize the network a free token would have to periodically pass through all of the other nodes on the network before allowing continued access. With CSMA/CD a node could transmit continuously until a collision occured with another user.

A ring network has the advantage of being deterministic. That is, the longest time that a node could possibly wait before being granted access to the network can be determined. All of the CSMA schemes are probabilistic, meaning that access cannot be assured let alone pinned down to a maximum time. In time sensitive applications, such as real time processing during high utilization periods, CSMA may not be able to provide acceptable response.

As noted in Stallings [Ref. 6: pp. 67-68], the choices of signaling method, transmission medium, topology and access method are all interrelated. To fix any one of these LAN elements will determine some of the other choices. The best of everything may not be possible and some trade-offs may have to be made. The objectives for the AS department LAN place minimal requirements upon LAN technology. Any viable combination of signaling method, medium, topology or access method should be able to provide the necessary throughput if combined with the right protocols and software.

B. STANDARDS

In order for devices on a network to be able to communicate with each other, they must all speak the same language. That is, the communications protocol must be the same. The International Standards Organization (ISO) has developed a model for networking computer systems called the Open Systems Interconnection (OSI) model. This model consists of sevens layers that provide related communications functions (see Table III). These layers when implemented with the same set of protocols in each node make computer networks possible.

In the OSI model each layer provides a particular communication service. The variety of service increases as more layers are used, beginning with the lowest layer, called the physical layer, which only supports the transmission of

TABLE III
SEVEN LAYER OSI MODEL

LAYER	FUNCTION
APPLICATION	USER NETWORK AND SERVICES
PRESENTATION	MANIPULATION AND CONVERSION OF STRUCTURED DATA
SESSION	COORDINATION AND SYNCHRONIZATION OF DIALOG
TRANSPORT	END-TO-END MESSAGE INTEGRITY
NETWORK	NETWORK ROUTING AND SWITCHING
DATA LINK	DATA TRANSMISSION AND RAW ERROR CHECKING BETWEEN TWO NODES
PHYSICAL	PHYSICAL INTERFACE BETWEEN DEVICES

unstructured bits and ending with the upper most layer, called the application layer that provides full user services.

A common protocol allows communication layers to provide network services between computer systems. Each computer system must use identical protocol for communications to be possible. Stallings [Ref. 6: p.37] defines the key elements of a protocol as syntax, semantics and timing. This deals with elements such as data format and signal levels, control and error handling procedures, and speed and sequencing of data. The OSI model is not itself a standard but it does provide the framework for many standards.

The implementation of all seven OSI layers would support distributed processing where each workstation could utilize

all of the processing power available to the user, not just peripherals. The typical LAN does not give this depth of support. Instead the typical off-the-shelf LAN implements only the first few OSI layers. This supports reliable communication between nodes and allows for shared peripherals and data files. Application programs are not shared in a distributed processing sense but a copy of an applications program can be sent to a mode in the same manner as a data file. This raises copyright questions that are still being debated.

The Institute of Electrical and Electronic Engineers (IEEE) 802 committee has developed a number of protocol standards for the first two OSI layers. Adherence to a network standard means that the network will be an open system that is able to utilize any product that follows the standard. This applies to software as well as hardware. The resulting network will be more easily expandable to include other equipment and users and will be more adaptable to changes in technology. Flexibility is important is an area as dynamic as computer technology.

Because local area networks do not support all seven OSI layers, some LANs have difficulty providing data security and integrity. A problem occurs when two users attempt to access the same file at the same time. If a second user is allowed access to a file before the first user has time to complete and file his changes, then the file that is saved last will be the only version that is kept. This can cause problems with multi-authored documents.

The LAN software must be able to keep multiple users from overwriting each other's file changes. This is often accomplished with semaphores or flags that indicate that a file is in use. It is important to note that not all software is designed to look for these flags. Thus a network product can say that it locks files to prevent overwriting,

but the particular applications software that is being used may not support that particular locking convention.

A full seven layer OSI network would not have to rely on the applications programs to provide data integrity. Instead the LAN software itself would provide all of the integrity and security functions, keeping the communications aspects of the network free of the applications that utilize the network.

III. LAN SERVICES

David Barcomb [Ref. 7: pp. 179-206] describes six stages in the life of an information document. They are:

- Creation
- Conversion
- Replication
- Distribution
- Filing and Retrieval
- Disposition

A microcomputer can be configured to support all six stages for an individual user. The result is an office automation system that greatly reduces the time and effort that the individual user spends on word management. A local area network facilitates communication between microcomputers integrating all of the individual nodes into an organization level system.

The basic services that a local area network must provide to support office automation at an organization level are:

- Compatibility with attached hardware
- Resource sharing
- File storage
- File transfer among users
- File retrieval
- Computerized Mail
- Interactive terminal-oriented message services
- Security of private files
- File lockout for data integrity
- File backup capability
- Directory of users, files and resources

A. COMPATIBILITY

A microcomputer uses a disk operating system (DOS) to control all of its peripheral communication such as reading and writing to files and output to monitor screens and printers. The DOS is the way that the microcomputer communicates with the outside world. For a computer to participate in a LAN there must be an interface between the DOS that the computer uses and the operating system that the LAN uses.

One of the biggest impediments to networking is the variety of DOSs that must be interfaced to the LAN. This is not a problem with the AS department LAN because all of the machines are from IBM or compatible with the IBM PC family of microcomputers and use a similar DOS. This greatly reduces the complexity of the network.

A Network Interface Unit (NIU) is added to each microcomputer in order to connect it to the LAN. This unit contains the LAN transmission and reception hardware. The logic that provides the interface between the microcomputer and the LAN and implements the LAN protocol may be in the NIU or it may be provided by the microcomputer. An intelligent NIU that has its own microprocessor to process LAN communication functions is more costly but also more efficient than a NIU that must share processing with its attached computer.

B. RESOURCE SHARING

In order for a resource to be shared via a LAN it must be addressable through the LAN. Individual peripherals such as a printer or a disk storage device are not normally directly accessible but must be addressed through a computer that acts as a file or print server.

Some LAN designs require the use of a special purpose computer to act as a dedicated server for the LAN. This adds to the cost of the LAN and limits the topology somewhat

by favoring centralized location of peripherals. Other LANs allow a microcomputer to act as a server which may limit the use of the microcomputer as a workstation.

C. FILES

The ease with which files are retrieved, updated and stored is highly dependant on the LAN operating system software. Most LANs have a sufficient transmission speed and capacity to provide the potential for transparent file operations. That is, a user should not be able to tell the difference between an access to a file that is resident at his workstation and an access to a file that is not at his workstation and must be completed through the LAN.

Data transmission speed is not a reliable indication of information transfer speed because it measures the transfer of raw bits only. It is therefore not possible to say that a LAN that has a data transmission rate of 10 Mbps can retrieve a file twice as fast as a LAN that has a 5 Mbps transmission rate. The overriding factor is the communications overhead imposed by the LAN software.

Ease of file operations is also affected by the detail of information that a user must have in order to access the file. Ideally a user should not have to specify the node and drive where a file resides in order to access the file. A truly transparent system would only list in a directory those files that a user had access rights to and would be able to provide access by file name alone. It is very easy to lose track of where a file really is in a network. It is unnecessary to require the user to supply addressing information.

D. MAIL AND MESSAGES

Electronic mail is similar to a letter. It is a file that is created by a user for the viewing of another user at some later time. All that is required is file space to

store the message and a method to prompt the receiving person that the mail file exists.

A computer message is similar to a telephone conversation in that it exists in real-time or is interactive between two or more users. For this to work the receiving node must be able to stop its current application processing long enough to inform the user that he has a message and allow the user to ignore the message or suspend his application work long enough to respond to the message.

Mail and message services both require a directory to list the users of the network. The ability to broadcast mail or a message to all users of the network is also a nice feature.

E. SECURITY

There are four major file access levels:

- no access or private files
- read only
- write only (useful for some databases)
- read and write or full access

File security varies from the most primitive locking schemes offered by DOS to a wide range of password access restrictions. Once again it is up to the LAN operating system to to enforce file security. This is done by intercepting DOS file commands from applications programs for processing by the LAN operating system. The level of security offered by a LAN is totally dependant on the quality of software that the LAN supports.

It would be nice to be able to control file access level by individual user. This is not possible in most LANs for reasons that are discussed in the Standards section of Chapter two. Instead most LANs that offer controllable file access use a password scheme to control access, requiring the user to maintain password integrity. The inability to limit file access by individual user stems from the fact

that most LANs do not have a single controlling unit but consist of peer related nodes.

F. BACKUP

File backup is critical to any computer system. It becomes even more difficult as files get spread around in a network. Common sense maintains that files should be backed up periodically as warranted by the content of the file. This is often a procedural question involving who will do the actual backup and how often the backup is to be performed.

G. ARCHIVING

Information has a useful life that is difficult to measure. Low cost, high volume electronic storage media make it even more difficult to purge information that has reached its useful life. The question of disposition of outdated information is often resolved by adding more storage which increases the overall cost of information processing for the organization.

Time and date stamping of files makes it easier to spot candidates for erasure or off line storage. In order to reduce unnecessary expansion, on-line storage should be reviewed periodically and files removed as necessary to provide adequate on-line storage for users.

IV. COMPARISON OF TWO SYSTEMS

With over two hundred LAN products on the market to choose from, picking the right network can be difficult indeed. It is not as simple as reviewing the specifications and trying to get the most features for the money. In their test of six prominent LAN offerings, PC World Magazine [Ref. 8: p. 118] determined that the specifications tell only part of the story. The proof of LAN performance can only be determined through operation of the LAN.

The minimum solution to the microcomputer networking problem should have the following characteristics:

- Easy installation
- Transparent operation
- Open, expandable architecture
- Limited access through logon passwords
- Support a minimum of 20 user workstations
- Maximum cable length of at least 1000 feet
- Allow more than one print server or printer location
- Provide a variety of file servers
- Security for private files
- Provide for electronic mail
- Provide interactive terminal-oriented message service

Of the six LANs that PC World tested only Netware's S/Net from Novell, Incorporated, fulfilled all of the above requirements. One LAN that was not in this test was the PC Network from IBM. These two LANs represent the top products on the market today. Any organization that is serious about implementing a LAN can look at these two products as representing the best that the network market has to offer.

A. NETWARE S/NET

Novell chose a star topology using twisted pair wiring for its S/NET [Refs. 8,9: pp. 108-128, pp. 131-134]. The network is capabile of supporting 24 nodes with a maximum cable length of 3000 feet from server to node. The central server is a special purpose microcomputer that is capable of supporting up to 500Mb of disk storage and 5 printers.

Installation of S-NET is uncomplicated, requiring only an interface board to be installed in each microcomputer. Twisted pair transmission medium is easy and inexpensive to install.

S/NET implements a true file server instead of the usual disk server. This means that the network can monitor file access at the applications program level rather than the more primitive DOS level. This is a more reliable method of locking active files from multiple users than the method used by disk servers. S/NET provides excellent speed, primarily do to its dedicated central hub (32-bit Motorola 68000 microprocessor) and logical seeking disk drive.

B. PC NETWORK

PC Network uses a broadband bus with CATV cable as a transmission medium [Ref. 10.] The network uses individual microcomputers as servers to provide access to printers and disk storage. No additional microprocessors are required.

The minimum network configuration requires an interface board, called an adaptor board[1] in each PC and a single headend or translator. This configuration will only support 8 PCs over a distance of 200 feet. With the addition of a base expander unit, the network is able to support up to 72 PCs at distances of up to 1,000 feet.[2]

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[1]The logic in the adaptor board implements the first five OSI network layers allowing greater communications capability than most LANs.

[2]Sytek, Inc., who provided the broadband hardware technology to IBM, has equipment that can expand the capacity of

PC Network utilizes IBM's network operating system and NETBIOS, or MS Net from Microsoft as its LAN operating system [Ref. 11.] Microsoft is the same company that wrote PC-DOS, the disk operating system that is used on IBM Personel Computers. MS Net proposes to be able to run existing programs as is and will be able to offer full LAN interoperability with only minor modifications.

There is no doubt that IBM is a significant player in the microcomputer market. The introduction of a LAN by IBM will help to generate some standardization in an otherwise unorganized environment. The market that IBM and IBM-compatible vendors command, will ensure that application programs are written with the necessary features to allow better file security and data integrity. This will also hasten the introduction of multiple user versions of the more popular PC software and bring to a head copyright issues that stem directly from networking.

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the IBM network to include 1,000 nodes at distances up to 3 miles.

V. CONCLUSIONS

Novell's S/NET would be a good choice for a large, single office network. Because of the star configuration, all of the peripherals are co-located with the central server. This would not be a convenient layout for an organization that is spread out over several floors as is the Administrative Sciences department.

The star configuration does allow heterogeneous computers access to the net. This may be the only option for organizations that have a wide variety of non-compatable computers.

Novell also puts out a low-budget version of S/NET that uses a microcomputer as the central server. This provides good performance for small networks. All of the other network components remain the same allowing the whole network to be upgraded by adding the dedicated server at a later time.

IBM's PC Network is more appropriate for decentralized organizations. It is expandable to service more nodes than S/NET and allows shared peripherals to be physically spread throughout an organization.

In those situations where either network is applicable, the decision becomes a cost value analysis between the total system costs and the services, applications and future expandability of the individual networks.

The Cadilac of computer networks is not the best solution for all organizations. It is easy to purchase more "network" than is necessary for the intended application. However future work loads and expansion capabilities must be considered in order for the network to remain useful for an acceptable period after purchase.

It is important to have a demonstration of the LAN in a configuration similar to that which will be used at the target installation to ensure that the LAN will perform as the user intends it to perform. The quality of services that LANs provide vary greatly and may not be representative of the product advertisement.

Assessing future needs can be difficult as the very implementation of a LAN opens new communication channels and fosters new information needs that are not easily foreseen by even the most diligent of planners. These new demands may quickly saturate a minimum-purchase network.

The LAN market is approaching critical mass. The near future will see a restructuring of the LAN market similar to that that which occurred in the personal computer arena recently. The resultant turmoil will have a profound effect on the numbers of independent LAN vendors and LAN products. It is logical to assume that only a few of the larger or more useable products and vendors will survive. Future applications program support and facilities maintenance depend on the ability of the company and the product to survive changes in technology and the market place.

APPENDIX

AS DEPARTMENT COMPUTER SURVEY

The following closed format questionnaire was distributed to all of the Administrative Sciences faculty. Twenty-five responses were received. Numbers inside the parenthesis indicate the number of responses that to that particular question segment.

As expected most faculty members have access to either a microcomputer or the mainframe computer. A significant number have access to both. One response indicated a preference for no access to any any computer.

The most interesting response was that to question 7. Most faculty do not feel that the time that they spend on paperwork detracts from their research or teaching. This is partly due to the heavy emphasis on microcomputers in the department and the abilities of the department support staff.

A questionnaire such as this highlights the varied equipment, application programs, computer experience and information needs in an organization. Hardware mismatch is easy to spot with a simple survey. The need for specialized applications programs or network services may require a more detailed survey.

QUESTIONNAIRE

NAME: ____________________ Department Mail Code: ______________

1. How do you perform the following functions now?

   A. Drafting of papers, memos or other wordprocessing functions.

(1)typewriter
(7)department Support Staff
(18)microcomputer
(3)other
(5)mainframe

B. Intra department communication.

(23)telephone
(18)personally
(16)messages (paper)
(9)mailbox/smc
(3)messages (mainframe)
(4)other

C. Communication external to the department.

(21)telephone
(11)personally
(17)messages (mailed)
(6)messages (electronic)
(3)other

2. Do you have access to a computer in your office.

(1)No, but I would like access
(1)No, and I don't want access
( ) Yes, via: (12)mainframe terminal
(22)microcomputer

3. If you have a microcomputer in your office:

A. What make and model computer do you use.

IBM PC- 17
XT- 5
AT- 1

B. Do you have any of these peripherals?

(19)printer (dot matrix)
(6)printer (daisey wheel)
(13)modem 1200 bd - 12
300 bd - 1
(14)hard disk 10 Mb - 10
20 Mb - 3
32 Mb - 1
(19)color/RGB monitor
(12)graphics card/capability

C. If you have a printer, how many pages to you print each week?

(8) less than 10
(6) 10 to 50
(4) 50 to 100
(2) over 100

D. If you have a modem, how often do you use it?

(7) less than once a day (4) about once a day

(3) more often than once a day

E. Do you use any of the following types of applications programs?

(17)word processing (10)spread sheet

(10)data base (7)language compiler

(7)graphics (5)modeling

(8)mathematical/statistical

(2)other programs of importance

F. What word processing program(s) do you use?

1. Word Perfect 4.0 - 8 2. Wordstar - 4
3. Multimate - 2 4. Script - 2 (Mainframe)
5. Peachtext, Perfectwriter, Edix/wordix - 1

4. Would you be interested in or use any of the following functions?

(12) electronic mail

(12) electronic message services (on line)

(14) file transfer

(9) program/data sharing

(15) access to mainframe (IBM)

(7) access to mainframe (VAX)

(5) access to DDN or other network

(15) use of centrally located peripherals such as a laser printer or a multi-color plotter.

(3) use of peripherals that are not centrally located

(7) ability to create private sub-nets with other net users

(1) removing some seldom used peripherals out of your office to a central location in order to have more room

5. Do you make regular use of the department support staff

(12) yes (12) no

6. How much time do you spend each week on paperwork that could be completed by the support staff?

(14) less than 1 hour (6) between 1 and 3 hours

(2) 3 to 6 hours (1) more than 6 hours

7. Do you feel that the time you spend on paperwork detracts from your research or teaching.

(7 yes (17) no

8. Has the department support staff been able to handle all of your requirements within a reasonable time frame.

(20) yes (0) no

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